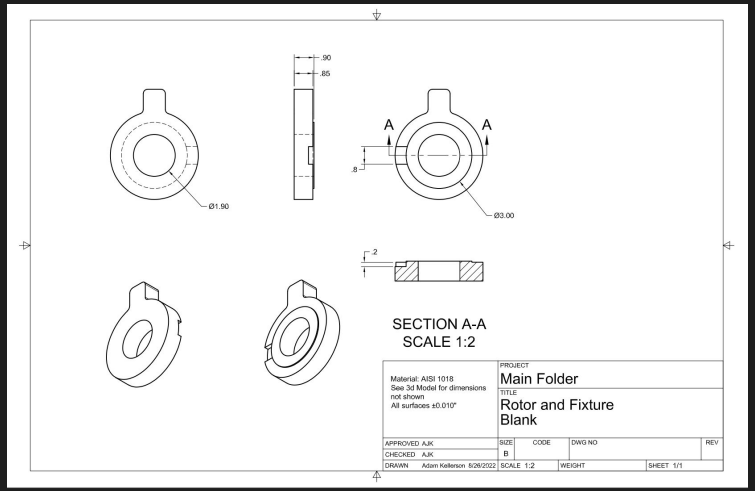
Process Development

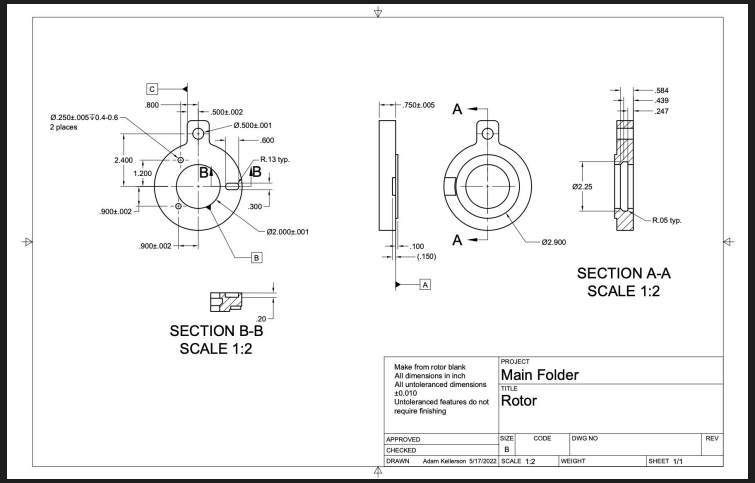
Gabe Mitchell, Roman Trujillo, Sourish Dutta, & Kassandra Nguyen

Objective

- Manufacturing 50,000 units/year for *Global Super Quality Precision Manufacturers*

- Choose CNC Equipment, fixturing, tools -> Create CNC paths -> Calculate tool loads -> Pricing and time





CNC Equipment (Dream Machine)

Dream Machine Specifications:

- Dual axis spindle head providing 245 deg of C-axis rotation and 120 deg of B axis tilt
- 5 axis simultaneous machining
- Supports large workpieces and fixtures
- Includes a 2-axis gimballed spindle to access most angles in complex shapes

CNC Equipment (Mill and Lathe)

Vertical Mill
(VF-2SS)

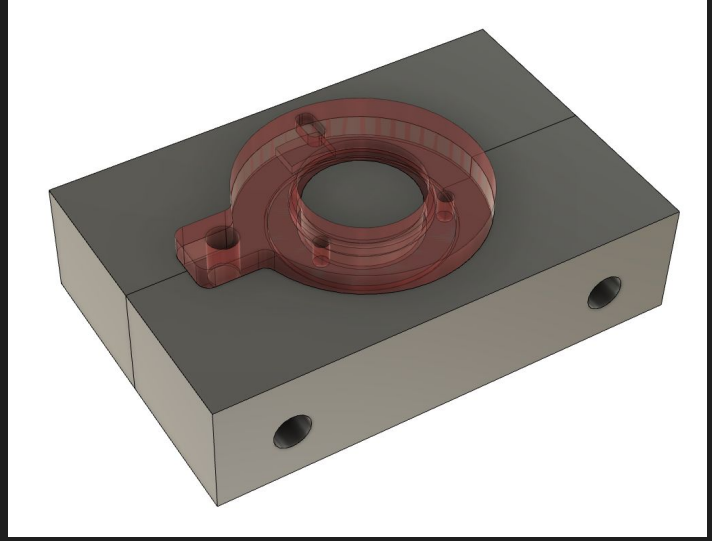
- Taper: 40
- RPM: 12000-RPM Spindle
- Tool Changer: High Speed 30+1 Side Mount
- Chip and Coolant: Window Air Blast with 55 Gallon Coolant Tank
- Other Features: Rigid Tapping

Chucker
Lathe
(CL-1)

- Chuck Size: 5C Nose
- Bar Capacity: 1.0”
- RPM: 6000-RPM Spindle
- Turrets and Live Tooling: 8 Station Tool Turret
- Chip and Coolant: Window Air Blast with 13 Gallon Coolant Tank

Work Holding Fixture

- Soft jaw: machined-in-place specific to rotor (blank file)
- Aluminum two-piece blocks to hold the rotor in place within the vice
- Center extrusion with close fit with given rotor stock
- Purpose: Facing off front and back profiles of rotor stock.



Cutting Tools - Op 1, Facing 1

Internal profiling tool

https://www.mcmaster.com/1450N11/

⅜ in endmill - https://www.mcmaster.com/8923A75/

Boring bar - https://www.mcmaster.com/3296A532/

31/64 in drill - https://www.mcmaster.com/2908A61/

½ in reamer - https://www.mcmaster.com/3106A78/

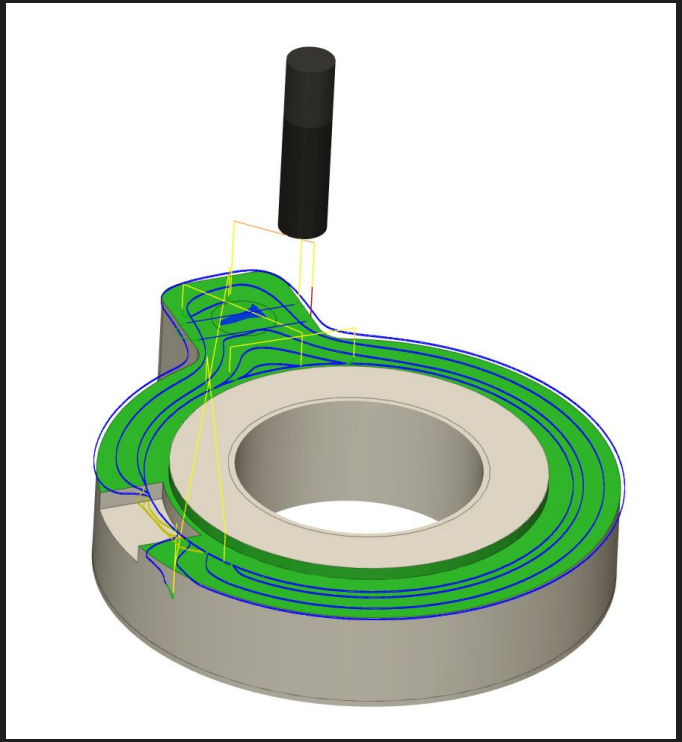
¼ in drill - https://www.mcmaster.com/2908A44/

Spot drill - https://www.mcmaster.com/2911A669/

3/16 endmill - https://www.mcmaster.com/3066A15/

Cutting Tools - Op 1, Facing

Large Endmill: D = 3/8”, 4 flutes, Carbide, TiN Coating



Cutting Tools - Op 2, Facing, Drilling, Slotting

Large Endmill: D = 3/8”, 4 flutes, Carbide, TiN Coating

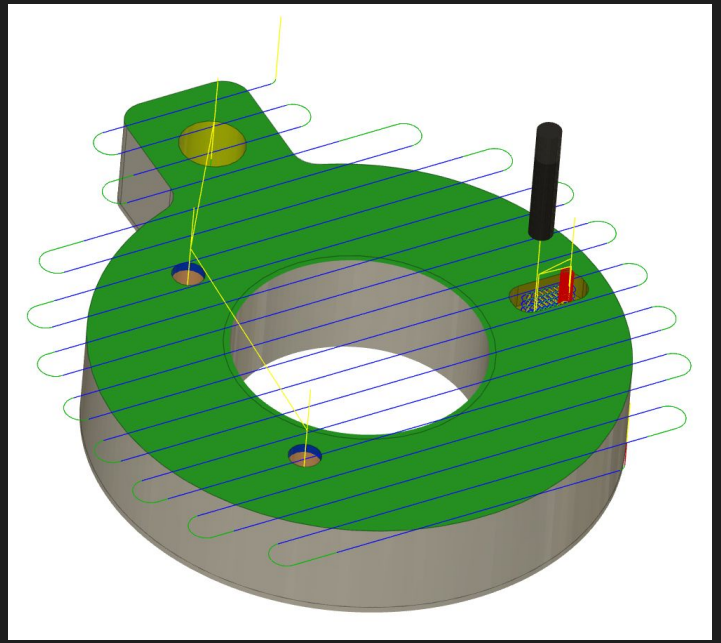
Slot Endmill: D = 3/16”, 4 flutes, Carbide, TiN Coating

Spot Drill: D = 1/4", 2 flutes, Carbide, TiAlN Coating

Small Hole Drill: D=0.25”, 2 flutes, Carbide, TiN Coating

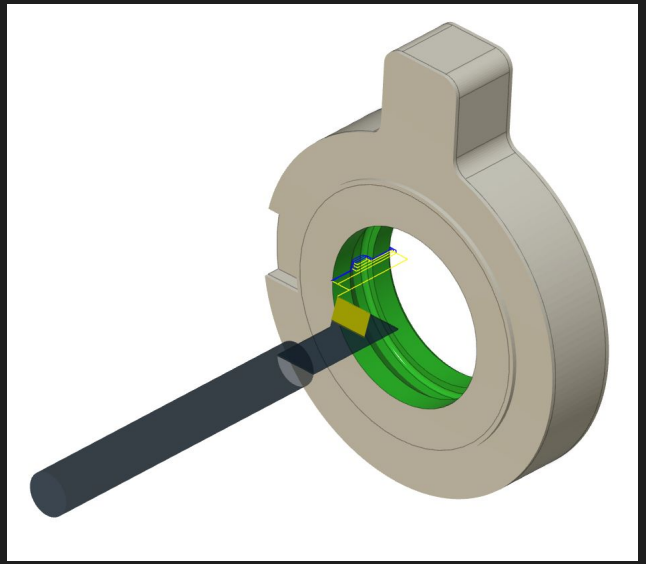
Large Hole Drill: D=31/64”, 2 flutes, Carbide, Uncoated

Reamer: D=0.5”, 10 flutes, HSS



Cutting Tools - Op 3, Boring, Internal Profiling

Boring Bar: Shape D, TiN coated, Carbide insert



Cutting Tools - Op 2, Facing, Drilling, Slotting

Large Endmill: D = 3/8”, 4 flutes, Carbide, TiN Coating

Slot Endmill: D = 3/16”, 4 flutes, Carbide, TiN Coating

S = sfm * 12 in/ft / (D * π) = 600ft * 12in/ft / (3/16in * pi) =

Spot Drill: D = 1/4", 2 flutes, Carbide, TiAlN Coating

Small Hole Drill: D=0.25”, 2 flutes, Carbide, TiN Coating

Large Hole Drill: D=31/64”, 2 flutes, Carbide, Uncoated

Reamer: D=0.5”, 10 flutes, HSS

Pic w face we’re machining this op facing us so that it’s clear what op we’re talking ab

Sfm values from:

Sfm Coated carbide cutting med/low carbon steel: 600sfm

Sfm uncoated carbide cutting med/low carbon steel: 400 sfm

Sfm HSS med/low carbon steel: 120 sfm

https://www.suncoasttools.com/PDFFILES/WhitneyTool/Catalog/35.pdf

Cutting Tools - Op 2, Facing, Drilling, Slotting

Tool	Diameter	Flutes	Material	Coating	Speed (RPM)	Feed (in/min)
Large Endmill	⅜ in.	4	Carbide	TiN Coating	6112	146.68
Slot Endmill	3/16 in.	4	Carbide	TiN Coating	12223	293.354
Spot Drill	¼ in.	2	Carbide	TiAlN Coating	9167	110.008
Small Hole Drill	¼ in.	2	Carbide	TiN Coating	9167	110.008
Large Hole Drill	31/64 in.	2	Carbide	Uncoated	3154	50.47
Reamer	½ in.	10	HSS	N/A	917	73.34

Calculation Script

```
D = [3/8, 3/16, 1/4, 0.25, 31/64, 0.5];
nt = [4, 4, 2, 2, 2, 10];
sfm = [600, 600, 600, 600, 400, 120];
ft = [0.006, 0.006, 0.006, 0.006, 0.008, 0.008];

speed = [];
feed = [];

for i = 1:length(D)
    speed(i) = (sfm(i)*12)/(D(i)*pi);
    feed(i) = (speed(i)*ft(i)*nt(i));
end
```

Used Constants:

- Sfm Coated carbide cutting med/low carbon steel: 600sfm
- Sfm uncoated carbide cutting med/low carbon steel: 400 sfm
- Sfm HSS med/low carbon steel: 120 sfm

All values obtained from the following website:

https://www.suncoasttools.com/PDFFILES/WhitneyTool/Catalog/35.pdf

Speeds and Feeds

Tool	Diameter	Flutes	Material	Coating	Speed (RPM)	Feed (in/min)
Large Endmill	⅜ in.	4	Carbide	TiN Coating	6112	146.68
Slot Endmill	3/16 in.	4	Carbide	TiN Coating	12223	293.354
Spot Drill	¼ in.	2	Carbide	TiAlN Coating	9167	110.008
Small Hole Drill	¼ in.	2	Carbide	TiN Coating	9167	110.008
Large Hole Drill	31/64 in.	2	Carbide	Uncoated	3154	50.47
Reamer	½ in.	10	HSS	N/A	917	73.34
Boring Bar	Variable	1	Carbide	TiN Coating	Variable	Variable

Calculation Script

```
D = [3/8, 3/16, 1/4, 0.25, 31/64, 0.5];
nt = [4, 4, 2, 2, 2, 10];
sfm = [600, 600, 600, 600, 400, 120];
ft = [0.006, 0.006, 0.006, 0.006, 0.008, 0.008];

speed = [];
feed = [];

for i = 1:length(D)
    speed(i) = (sfm(i)*12)/(D(i)*pi);
    feed(i) = (speed(i)*ft(i)*nt(i));
end
```

Used Constants:

- Sfm Coated carbide cutting med/low carbon steel: 600sfm
- Sfm uncoated carbide cutting med/low carbon steel: 400 sfm
- Sfm HSS med/low carbon steel: 120 sfm

All values obtained from the following website:

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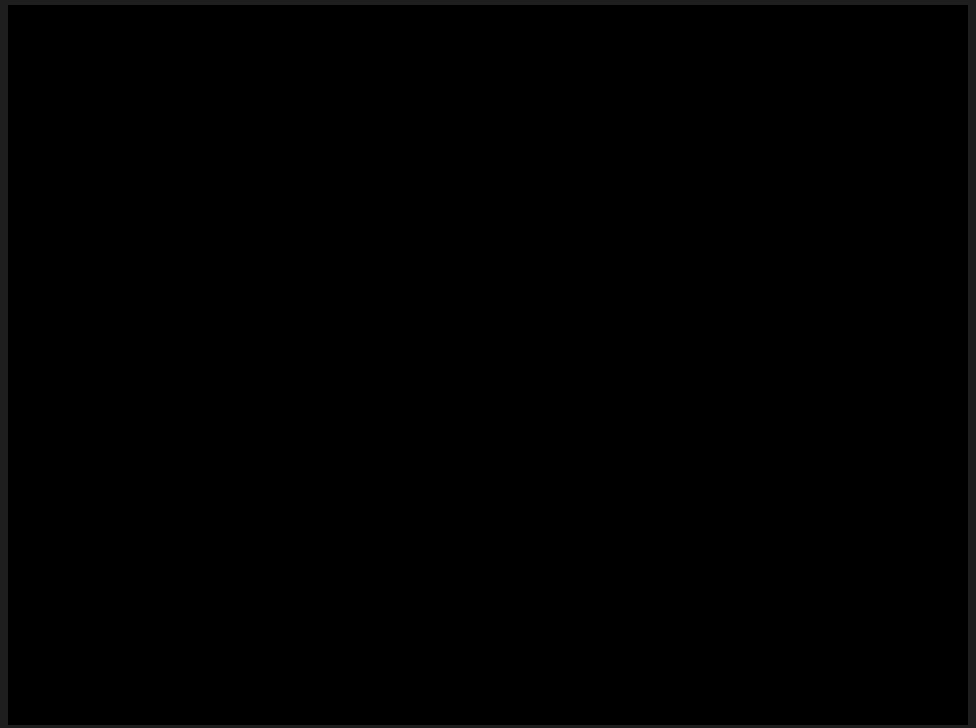
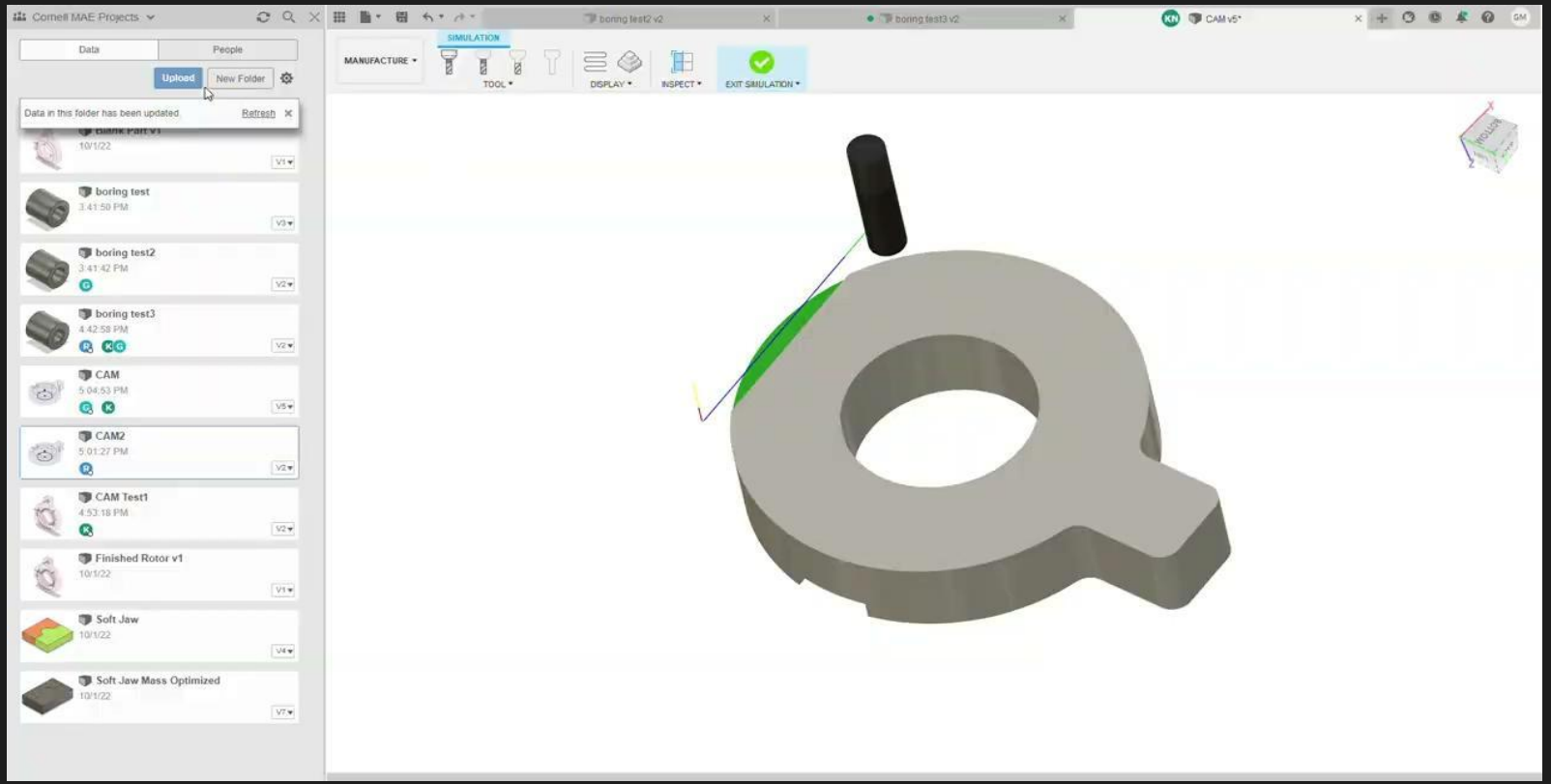
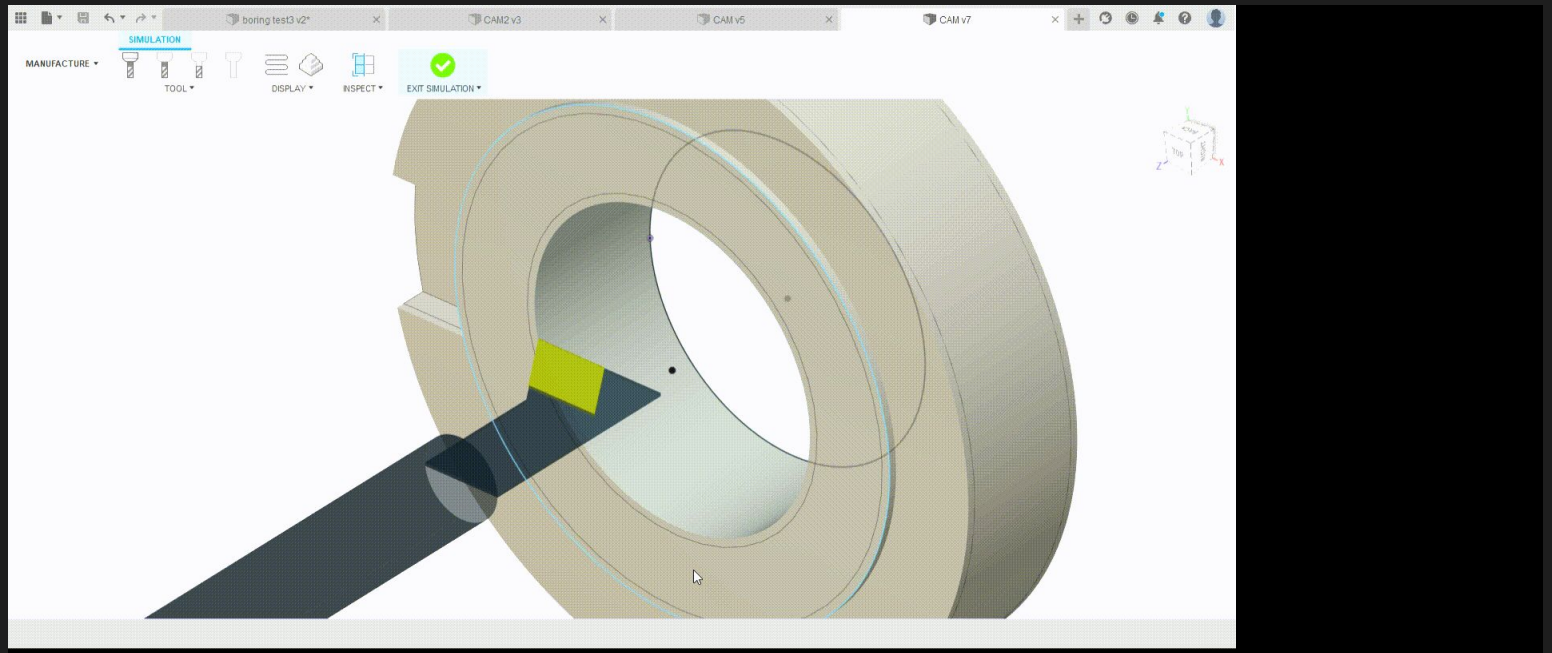
CNC Paths - OP 1



CNC Paths - OP 2



CNC Paths - OP 3



Tool Load

Tool	Width of Cut (in)	Depth of Cut (in)	Feed (in/min)	Material Removal Rate	Unit Horsepower	Force Requirement (HP)
Large Endmill	0.15 in.	0.04 in.	146.68	**0.8801**	1.82	**1.6017**
Slot Endmill	3/16 in.	0.06 in.	293.354	**3.3002**	1.82	**6.0064**

Calculation Script

```
woc = [0.15, 3/16];
doc = [0.04, 0.06];
feed = [146.68, 293.354];
mrr = woc.*doc.*feed;
UHp = 1.82;
HP = UHp * mrr;
```

Tool	Diameter of Cut (in)	Area of Cut (in^2)	Feed (in/min)	Material Removal Rate	Unit Horsepower	Force Requirement (HP)
Spot Drill	¼ in.	0.0491	110.008	**5.4**	1.82	**9.82**
Small Hole Drill	¼ in.	0.0491	110.008	**5.4**	1.82	**9.82**
Large Hole Drill	31/64 in.	0.1843	50.47	**9.3**	1.82	**16.9261**
Reamer	½ in.	0.1963	73.34	**14.4**	1.82	**26.2085**

Calculation Script

```
woc = [1/4, 1/4, 31/64, 1/2];
area = (pi/4)*(woc).^2;
feed = [110.008, 110.008, 50.47, 73.34];
mrr = area.*feed;
UHp = 1.82;
HP = UHp * mrr;
```

Tool Load

Tool	Width of Cut (in)	Depth of Cut (in)	Feed (in/min)	Material Removal Rate	Unit Horsepower	Power Requirement (HP)	**Cutting Force (lbf)**
Large Endmill	0.15 in.	0.04 in.	146.68	**0.8801**	1.82	1.6017	**66**
Slot Endmill	3/16 in.	0.06 in.	293.354	**3.3002**	1.82	6.0064	**248**

Tool	Diameter of Cut (in)	Area of Cut (in^2)	Feed (in/min)	Material Removal Rate	Unit Horsepower	Power Requirement (HP)	**Cutting Force (lbf)**
Spot Drill	¼ in.	0.008	110.008	**0.88**	1.82	1.6	**66**
Small Hole Drill	¼ in.	0.0491	110.008	**5.4**	1.82	9.82	**405**
Large Hole Drill	31/64 in.	0.074 (after predrilling)	50.47	**3.73**	1.82	6.8	**280**
Reamer	½ in.	0.012 (after predrilling)	73.34	**0.88**	1.82	1.6016	**330**

Calculation Script

```
woc = [0.15, 3/16];
doc = [0.04, 0.06];
feed = [146.68, 293.354];
mrr = woc.*doc.*feed;
UHp = 1.82;
HP = UHp * mrr;
```

Calculation Script

```
woc = [1/4, 1/4, 31/64, 1/2];
area = (pi/4)*(woc).^2;
feed = [110.008, 110.008, 50.47, 73.34];
mrr = area.*feed;
UHp = 1.82;
HP = UHp * mrr;
```

Efficiency = 0.75

Time Estimation

OP 1 - 46 seconds

OP 2 - 3 minute 41 seconds

OP 3 - 19 seconds

Total machining time for 1 part: 4 minutes 46 seconds

Total machining time for 50000 parts: 3972 hours

Thank You